



International and national laws work together for the governance of space activities

Art Dula

Attorney at Law, Houston, Texas USA

Academician

International Academy of Astronautics



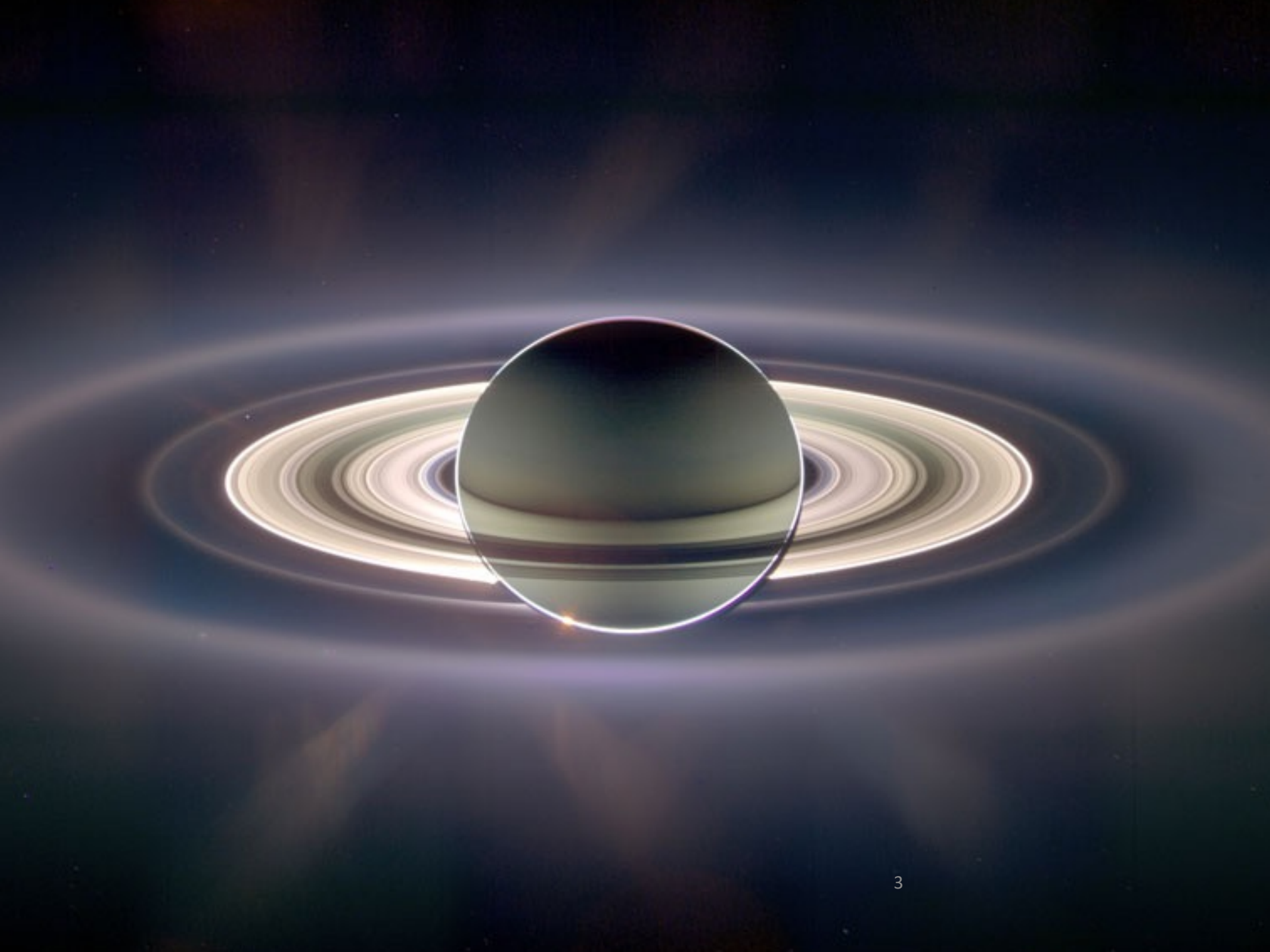
Future Frontiers: Space Law I
Thought Leader Series
Tuesday, August 13, 2024
6:45 pm



**Space
Center
Houston**

No one sees the future coming.

- **This “telephone” has too many shortcomings to be seriously considered as a practical form of communication. The device is inherently of no value to us.**
 - *Western Union internal memo, 1878*
- **Heavier-than-air flying machines are impossible.**
 - *Lord Kelvin (1824-1907), British mathematician and physicist, 1895*





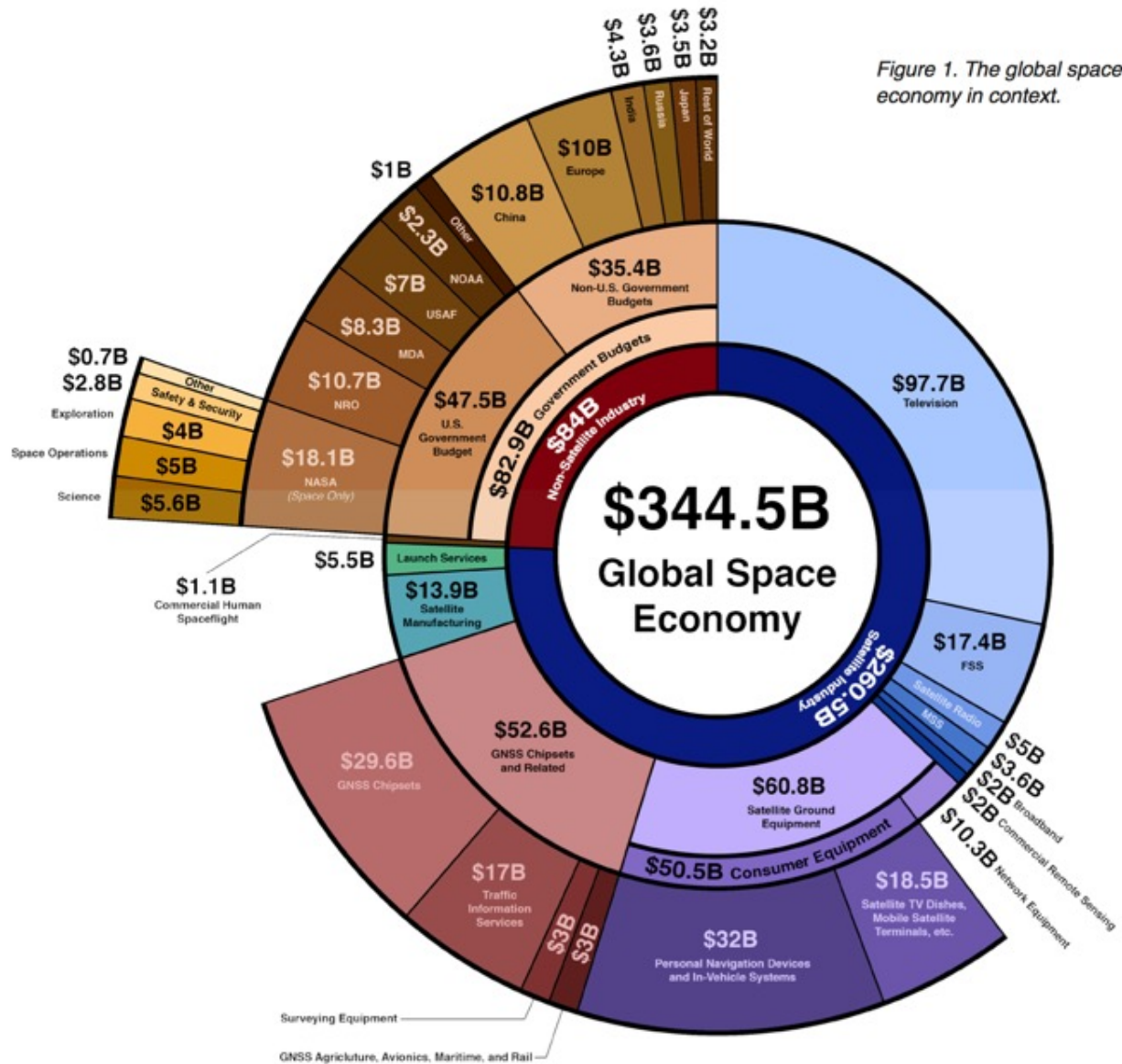
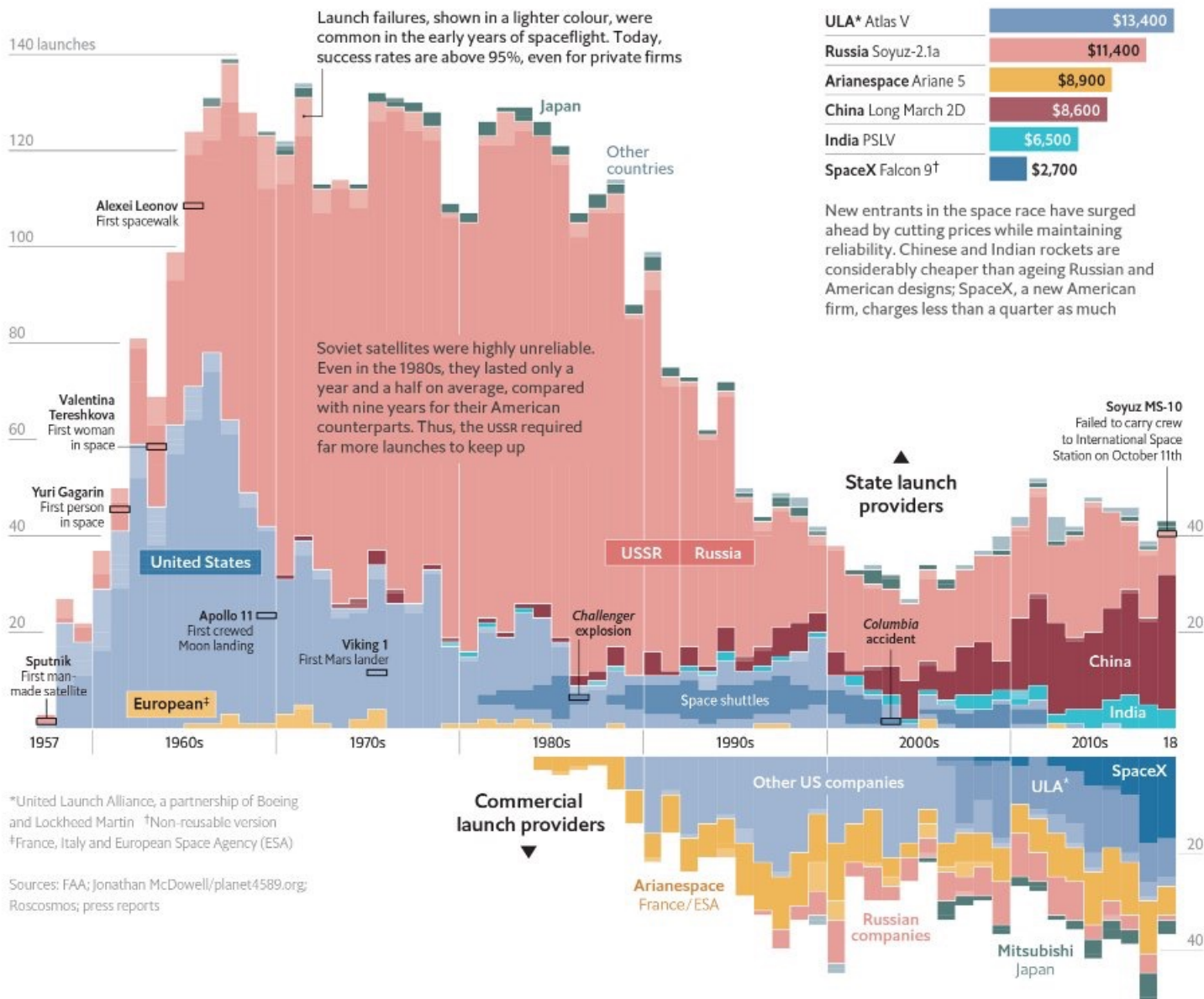


Figure 1. The global space economy in context.

Space launches

To Earth orbit or higher, at October 17th 2018



*United Launch Alliance, a partnership of Boeing and Lockheed Martin

†Non-reusable version

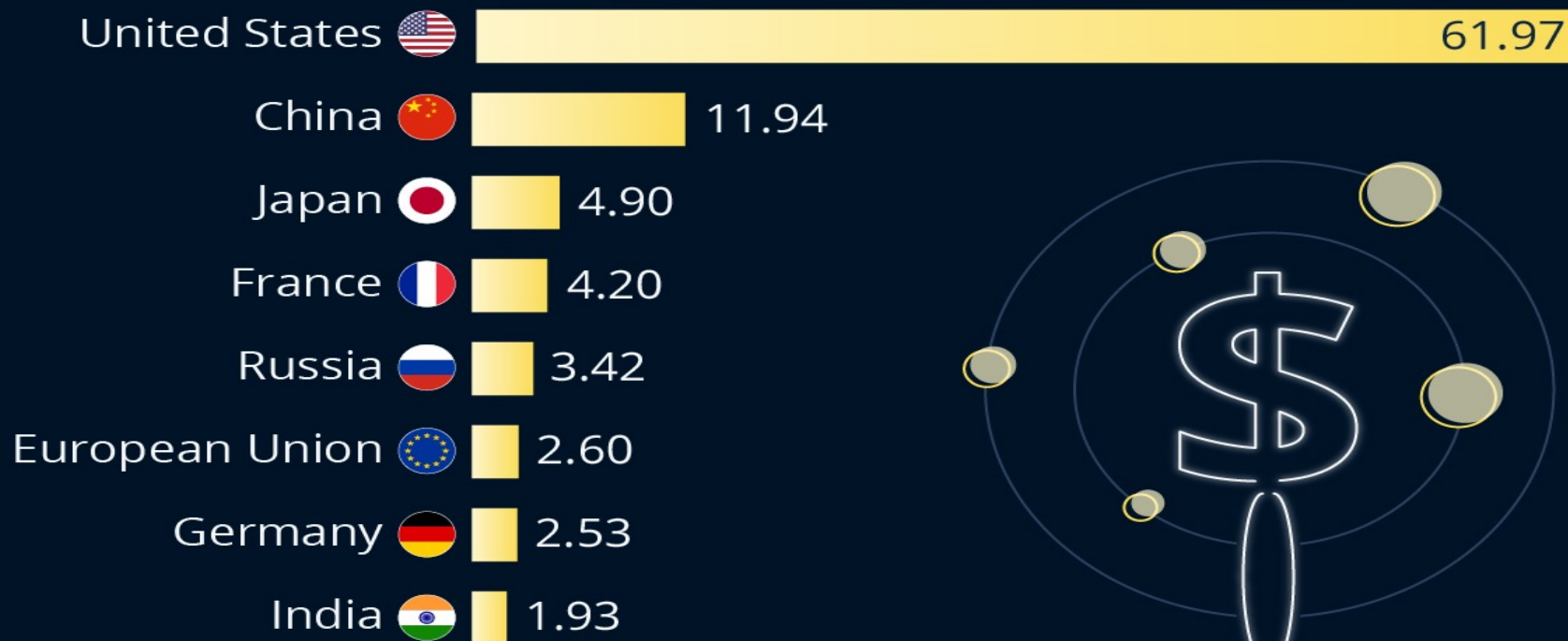
‡France, Italy and European Space Agency (ESA)

Sources: FAA; Jonathan McDowell/planet4589.org;

Roscosmos; press reports

The Governments With the Largest Space Budgets

Government expenditure on space programs in 2022
(in billion U.S. dollars)



Figures for European countries include contributions to ESA and Eumetsat.
Source: Euroconsult - EC

ULA
America's Ride to Space

Road Map to the CisLunar-1000 Economy

Part 1: TODAY



GROSS SPACE PRODUCT \$330B/YR

POPULATION x5

ULA
America's Ride to Space

Road Map to the CisLunar-1000 Economy

Part 2: 5 YEARS



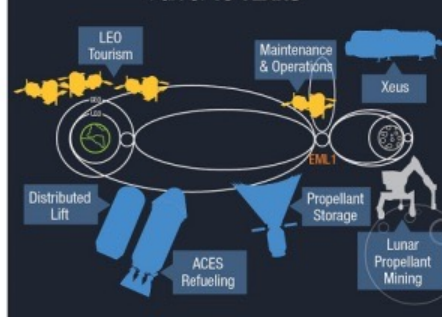
GROSS SPACE PRODUCT \$500B/YR

POPULATION x20

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America's Ride to Space

Road Map to the CisLunar-1000 Economy

Part 3: 15 YEARS



GROSS SPACE PRODUCT \$900B/YR

POPULATION x300

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America's Ride to Space

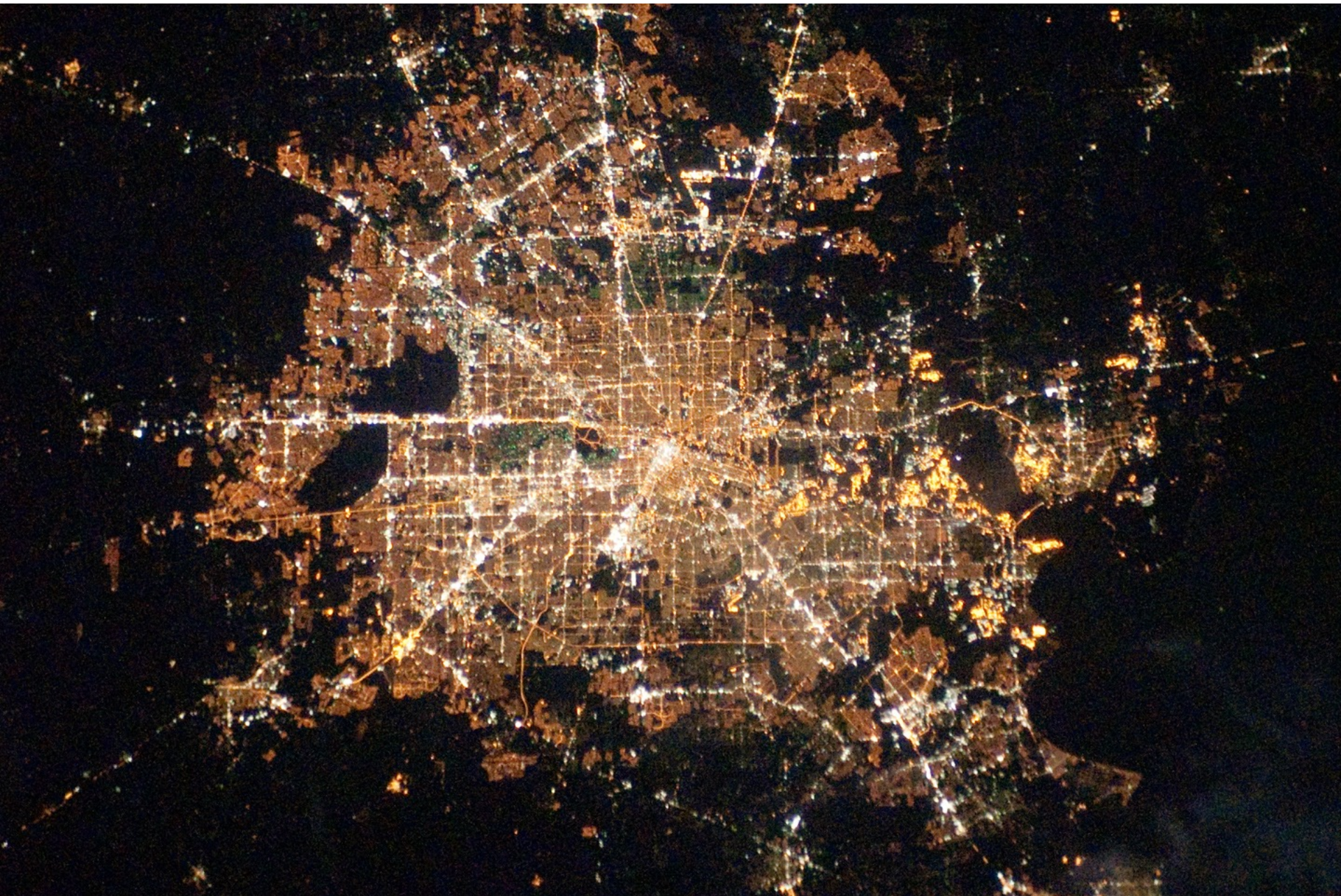
Road Map to the CisLunar-1000 Economy

Part 4: 30 YEARS



GROSS SPACE PRODUCT \$2.7T/YR

POPULATION x 1,000



The image shows a large, illuminated sign for the Houston Spaceport. The sign features the words "HOUSTON SPACEPORT" in large, white, three-dimensional capital letters. Above the text is a large, red, illuminated arch that resembles a stylized orbit or a path. To the left of the arch, a sculpture of a rocket ship is visible, pointing upwards and to the left. The entire structure is set against a clear blue sky, and the foreground consists of dark, low-lying vegetation.

HOUSTON SPACEPORT

Sources of Space Law

- Traditional Law
- International Treaties
- International Agreements
 - National Laws
- National Regulations
 - National Policy

International Law

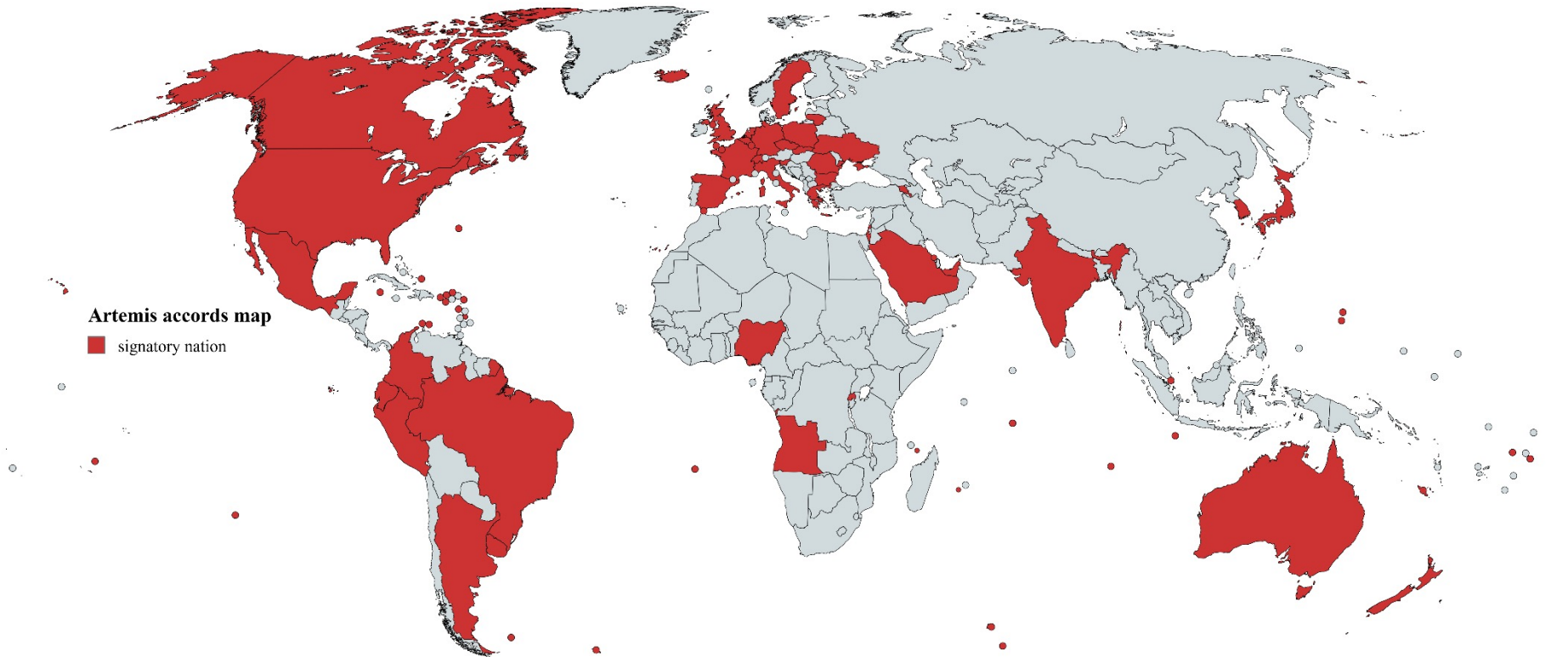
- United Nations Committee for the Peaceful Use of Outer Space
 - Outer Space Treaty – 1967 – a cold war compromise
 - No claim of sovereignty allowed
 - State responsibility for damage done by private actions
 - Rescue and Return Agreement – 1968
 - Liability Convention for damage done by space objects – 1972
 - Registration Convention – 1976
 - “Moon Agreement” – 1979 – not widely adopted
- United Nations Resolutions (nonbinding)
 - Direct Broadcast TV
 - Nuclear Power use in space
 - Remote Sensing
 - Role of National Law

International Agreements

- Intergovernmental Agreement for the Space Station
 - Sets the program duties of each partner state
 - Defines jurisdictional authority over station elements
 - Sets rules for intellectual property and data security
 - Defines jurisdictional authority over crew members
 - Limits liability between partner states
- Multilateral and Bilateral agreements for space cooperation
 - Brazil and Ukraine for use of Alcântara launch site
 - Remote sensing ground stations
 - Scientific cooperation for interplanetary stations and landers
 - Latest is the **Artemis Accords**: a series of non-binding multilateral arrangements between the United States government and 42 other world governments as of June 2024 that elaborates on the norms expected to be followed in outer space.

Artimus Accords states (June 2024)

CHINA AND RUSSIA HAVE NOT JOINED



Hierarchy of Law



U.S. Constitution - Amendment 10

Amendment 10 - Powers of the States and People

The powers not delegated to the United States by the Constitution, nor prohibited by it to the States, are reserved to the States respectively, or to the people.

the
TENTH AMENDMENT
was written to emphasize the
★ **LIMITED NATURE** ★
of the powers
★ **DELEGATED** ★
to the federal government.

tenthamendmentcenter.com/about10th

US National Space Law

- Consitution
- Federal Statutes:
 - NASA Act – 1958
 - Commercial Space Act of 1998
 - FCC Act – ITU – communications satellites
 - FAA – Commercial Launch Act
 - Commercial Remote Sensing Act
 - General Jurisdiction extended to US registered spacecraft
 - Patent Law extended to US registered spacecraft
 - Law controlling crew on the space station
 - Export control and national security law
- State and Local Law – What applies in Space?
 - Marriage on the MIR – Texas
 - Wrongful Death of Astronauts
 - Contracts and torts generally are state laws in the USA

Background

- The U.S. space program today has 3 sectors:
 - Civil (NASA)
 - Military (Department of Defense – CIA – NRO)
 - Commercial -Federal Aviation Administration (FAA)
 - Licensing and Regulation does not control industry - Market
- The commercial sector was created in 1984 with the passage of the Commercial Space Launch Act.
- Responsibility for this sector was given to the Office of Commercial Space Transportation, which was originally a staff office within the Department of Transportation.
- Today, space transportation is one of the lines of business within the FAA.

Who Needs a Launch License?

- Commercial Space Launch Act of 1984 requires U.S. citizens to obtain a license prior to conducting the launch of a launch vehicle
- Only exception is for missions conducted by and for the government (such as launches by NASA or the U.S. Air Force)
- Over the last 20 years, there have been 170 licensed launches, without any fatalities or property damage to the uninvolved public.

Spurring Private Aerospace Competitiveness and Entrepreneurship Act of 2015

Signed by President **Barack Obama** on 25
November 2015 explicitly allows



“US citizens to engage in the commercial exploration and exploitation of 'space resources' [including ... water and minerals].”

The Act further asserts that "the United States does not [(by this Act)] assert **sovereignty** or sovereign or **exclusive rights** or jurisdiction over, or the ownership of, any **celestial body**.

Fig. 4 – NASA Cost Analysis Comparing NASA’s Predicted Cost vs. SpaceX Falcon 9 Actual Costs: >10X Cost Reduction (NASA 2011)

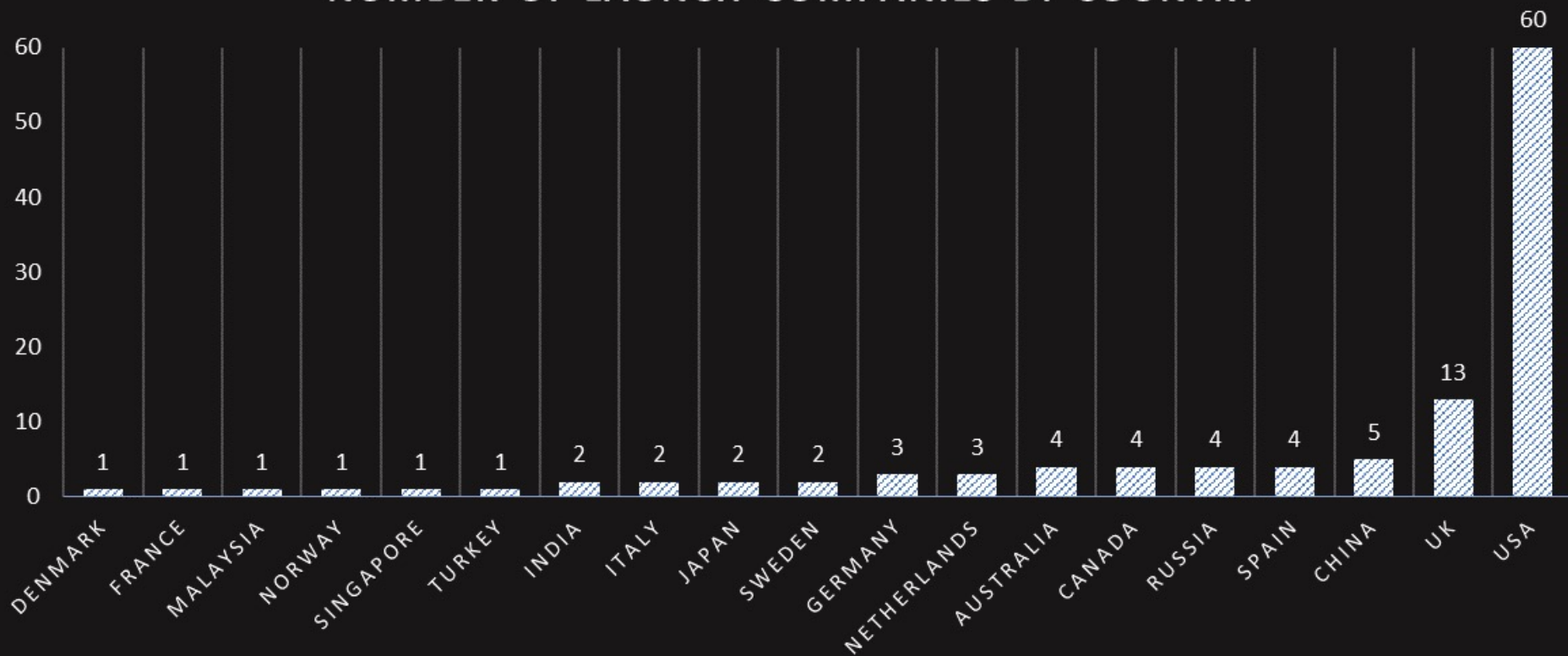
		NASA Model Based Prediction			SpaceX Actual Performance			
		NASA Approach			Firm Fixed Price Acquisition			
Elements	Weight (lbs)	DDT&E (FY2010 \$M)	Flight Unit (FY2010 \$M)	Total (FY2010 \$M)	Weight (lbs)	DDT&E (FY2010 \$M)	2 Test Flt Units (FY2010 \$M)	Total (FY2010 \$M)
Stage One (Including Engines)	39,080	\$1,535	\$206	\$1,741	39,080	\$188.7	\$109.3	\$298.0
Stage Two (Including Engine)	6,520	\$608	\$44	\$651	6,506	\$89.0	\$23.6	\$112.6
Fee (12.5%)		\$268	\$30	\$298		\$0.0	\$0.0	\$0.0
Program Support (10%)		\$241	\$21	\$263		\$0.0	\$0.0	\$0.0
Contingency (30% Vehicle, 10% Engine))		\$674	\$68	\$741		\$0.0	\$0.0	\$0.0
Vehicle Level Integration (8%)		\$258	\$24	\$282		\$22.2	\$10.6	\$32.8
Total	45,600	\$3,584	\$393	\$3,977	45,586	\$299.9	\$143.6	\$443.4
>10X Cost Reduction								

Equity Investments From 2009 To Present

10 Companies
\$147 M

1969	1983	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
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NUMBER OF LAUNCH COMPANIES BY COUNTRY



Data from the SpaceFund Reality rating Launch Database











Payload capacity

100,000 kg (220,000 lb; target is 150 metric tons) 100 passengers

Length: 50 m (160 ft)

Production Status: In development

Built: 3 [test articles](#)

Range: Anyplace on Earth in 45 minutes; Earth orbit; if refueled in space, Moon or Mars





Any sufficiently advanced technology is
indistinguishable from magic.

Arthur C. Clarke

One man's 'magic' is another man's engineering.
'Supernatural' is a null word.

Robert A. Heinlein

Experimental design of a semiconductor propulsion device using the dynamic Casimir effect to transfer momentum to an object by interaction with the electromagnetic field ground state.

"One of the most surprising predictions of modern quantum theory is that the vacuum of space is not empty. In fact, quantum theory predicts that it teems with particles flitting in and out of existence." Christopher Wilson, Chalmers University, Sweden, in his paper "Observation of the Dynamical Casimir Effect in a Superconducting Circuit." arxiv.org/abs/1105.471

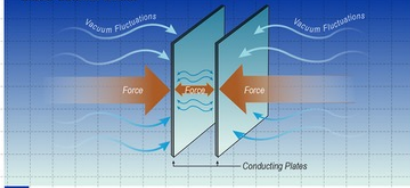
If two conductive plates are held close together and parallel to each other they will be pushed together when the gap between them is smaller than the wavelength of some of the virtual particles. This causes the vacuum pressure inside the gap to be less than the vacuum pressure outside, forcing the plates together.

This force is the **static Casimir effect**. It was first measured by two teams in the US in 1998. When the conductors are separated by distance of about 10 atomic diameters, the Casimir force is roughly equal to air pressure at sea level; about 96,000 N per square meter.

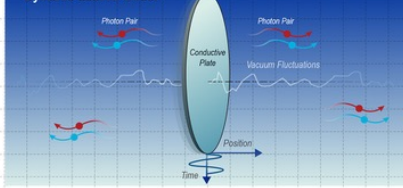
Another force, the **dynamical Casimir effect**, is produced when a single conductive plate is moved at relativistic speed. At slow speeds, virtual particles can adapt to the conductor's movement and continue to come into existence in pairs and then disappear as they annihilate each other. However when the speed of the conductor approaches the speed of the photons; i.e. at an appreciable fraction of the speed of light, some photons become real causing the moving conductor to transfer momentum from empty space and produce light.

It is mechanically impossible to move a large area conductor at relativistic speed over a significant distance. Wilson, cited above, modulated a superconducting quantum interference device to achieve about 5% of the speed of light over the distance of about a nanometer near a transmission line a hundred micrometers long. This movement produced microwave photons. It was the first experimental observation of the force produced by the dynamical Casimir effect.

Static Casimir Effect



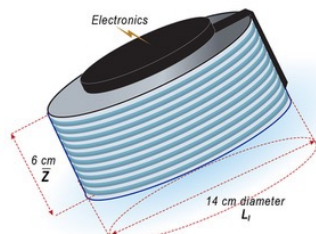
Dynamical Casimir Effect



The device operates by changing the position of the conductive region in a large scale (cm to meters) semiconductor structure by successively applying an electric field at different positions in the semiconductor structure without requiring mechanical motion. Movement of a large area conductor through a large distance at relativistic velocity produces a dynamical Casimir force strong enough to be useful for propulsion and for other purposes.

Parameter Estimates - This table summarizes the nominal values of the design parameters so far estimated.

Quantity	Definition	Nominal Value
$\{$	Exponent in the power law acceleration profile	2
k_U	Upper end of the active wave number range	$2 \times 10^8 \text{ m}^{-1}$
k_L	Lower end of the active wave number range	$0.3 \times 10^8 \text{ m}^{-1}$
Ω_{MAX}	Maximum scan frequency	1GHz
t_R	Minimum switching pulse rise time	1 ns
$\bar{V}$	Maximum speed in the acceleration profile	0.95 c
$\bar{Z}$	Total force producing stroke of the acceleration profile	6 cm
N_f	Number of laminae	>10
∂	Lamina thickness	5 mm
r_i	Maximum lamina reflectivity	>0.2
t_t	Maximum lamina transparency	0.995
L_i	Circular lamina diameter	14 cm



Tasks Completed

1. Thoroughly review and correct, as necessary, the theoretical analysis of the force that can be produced by the device, particularly for the unrestricted (large) amplitude case.
2. Perform design trade-off comparisons, determining force capability, size, dimensions of the laminae, wavelength range, power requirements, etc.
3. Researching the literature to identify semiconductor or liquid crystal devices for which there is a wavelength range where the device can be switched from reflector to transparency, and vice versa. Estimate the achievable active wavelength band, and switching frequency.
4. With a preliminary design, based upon Tasks (2) and (3), formulate the specifications for the manufacturer.

THE ADVANCED PROPULSION WORKSHOP

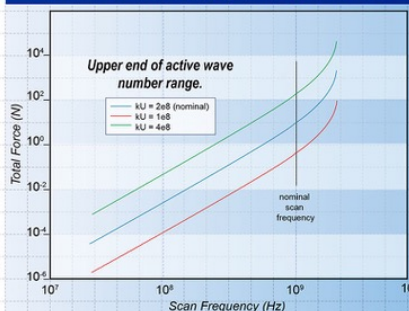


The theoretical review of the fundamental concepts of the epitaxial device was presented at the Advanced Propulsion Workshop held at the Aerospace Corporation, El Segundo, California, November 1-3, 2017, and submitted as the paper "An Epitaxial Device for Dynamic Interaction with the Vacuum State" to the *Journal of the British Interplanetary Society*.

ASSUMPTIONS

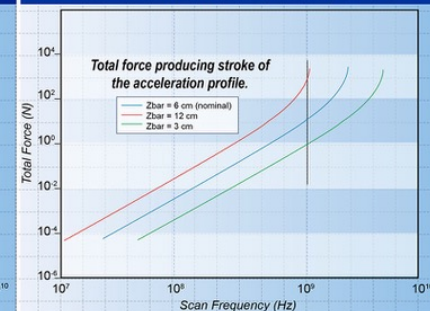
The general objective of the study is the determination of specifications for an experimental device consisting of an epitaxial stack of modest dimensions (< 0.3m), capable of producing forces that are significantly above the threshold of detectability (between 1 and 10 N). It is assumed that within certain wavelength bands, the reflectivity of each lamina can be set within a continuous range from completely reflective to completely transparent. The laminae are also characterized by a finite response time. These features can be combined so that when the laminae are sufficiently closely spaced, and their energizing processes are properly phased, a multi-lamina propagating wave of reflectivity can be created that sustains the properties of a continuously moving mirror.

Nominal Values, except k_U varied by a factor of 2



Calculation of the force produced by the nominal design, compared with results produced by varying k_U .

Nominal Values, except Z_{bar} varied by a factor of 2



Calculation of the force produced by the nominal design, compared with results produced by varying Z .

CONCLUSION

An in-depth investigation of the lamina switching algorithm was performed. From the performance analysis, details of the switching algorithm were refined, and the greatly improved "one-sided continuous array" design was developed. The updated design significantly reduces the device complexity and fabrication precision required while permitting much higher peak accelerations of the motion profile (hence, higher force outputs). Integrating these refinements with the design, we performed trade-off analyses considering the more than dozen significant design parameters. A nominal design was developed meeting our goal of 1N to 10N force produced by a test device with size scale about 10cm. The sensitivities of this design to variations in the design parameters was explored. Within the state of our present knowledge, the nominal design can attain performance well above the edge of detectability, and there is considerable latitude in selecting design parameters to sustain this capability.

THE FUTURE

Will Excalibur's proposed 'proof of concept' device produce a measurable force? If it does, how much force?

If only a few Newtons, it could replace Hall thrusters. If an embodiment of the device could be built that produces a few hundred kilo-Newtons, it could lift our proposed 32mT space station directly from the Earth's surface to space without requiring a rocket launch vehicle. This would be a truly extraordinary result.



Cosmic cornucopia

©NewScientist

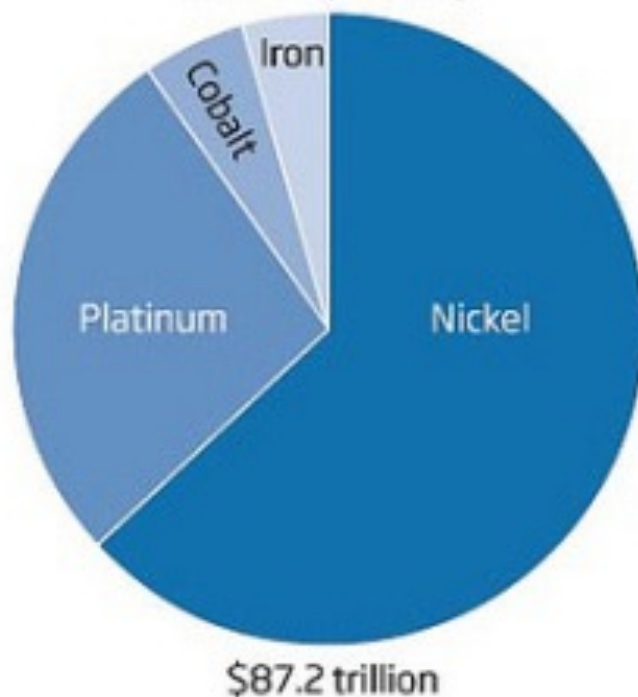
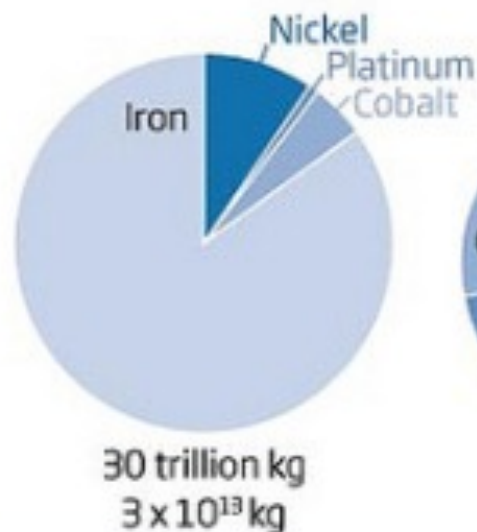
Asteroids could be a valuable source of metals. In 1994, William Hartmann at the Planetary Science Institute estimated the value of a 2-kilometre-wide metal rich asteroid

Asteroid 1986 DA

Value (2012)

Composition

Value (1994)



US debt



SOURCE: LONDON METAL EXCHANGE/PLATINUM TODAY

Always listen to
experts. They'll
tell you what can't
be done and why.
Then do it.

Robert Heinlein

meetville.com



Editors:
Arthur M. Dula
Zhang Zhenjun

Space Mineral Resources
A Global Assessment of the
Challenges and Opportunities

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International Academy of Astronautics



外空矿物资源

——挑战与机遇的全球评估

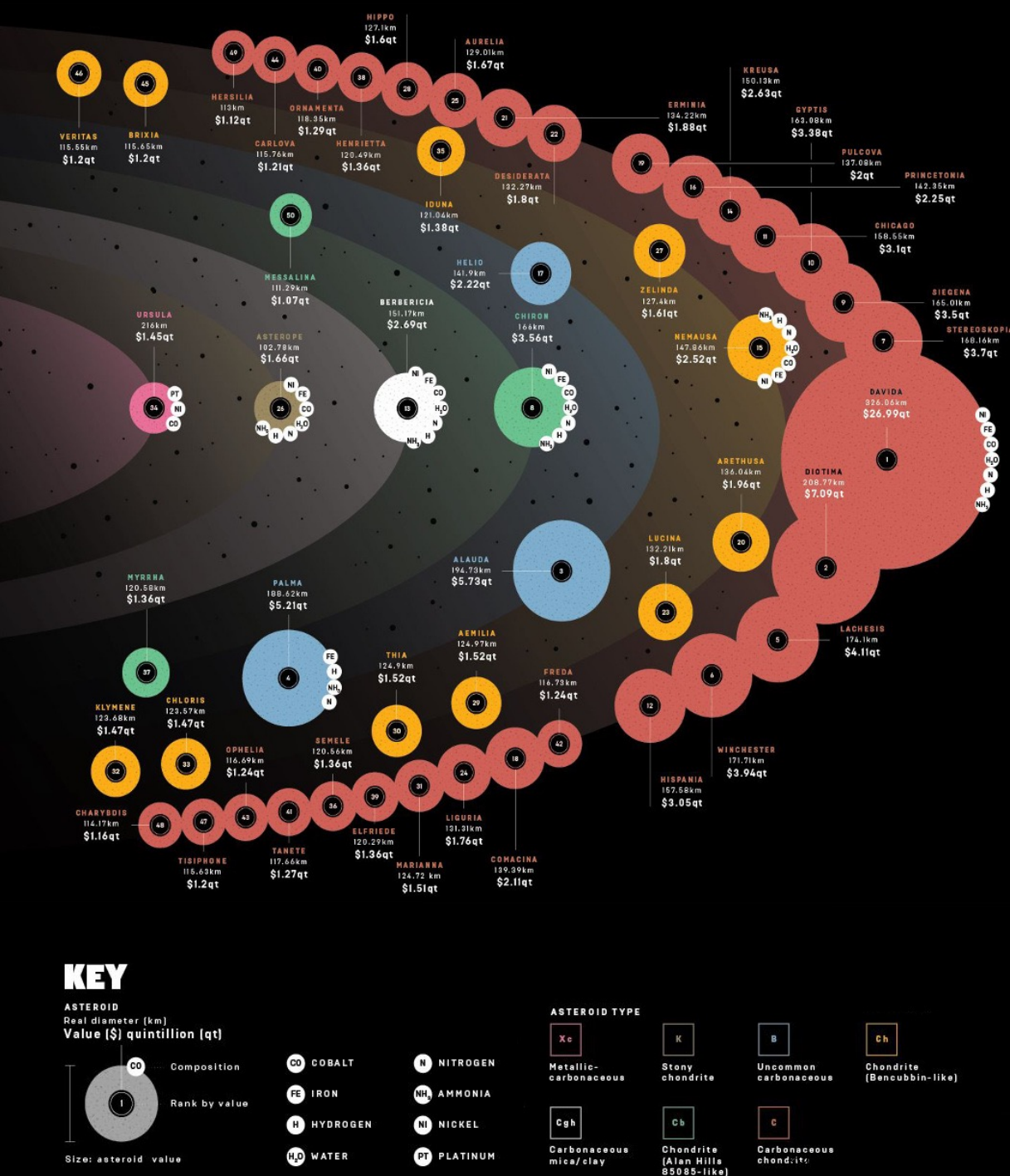
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[美] 阿尔瑟·M·杜勒 (Arthur M. Dula) [中] 张振军 主编
中国航天科技国际交流中心 编译



 中国宇航出版社

The resources of our solar system are effectively infinite. The mineral wealth of just 50 asteroids would be enough to support a civilization of more than 10 trillion people.



Where do you want your grandchildren to be at the end of this century?

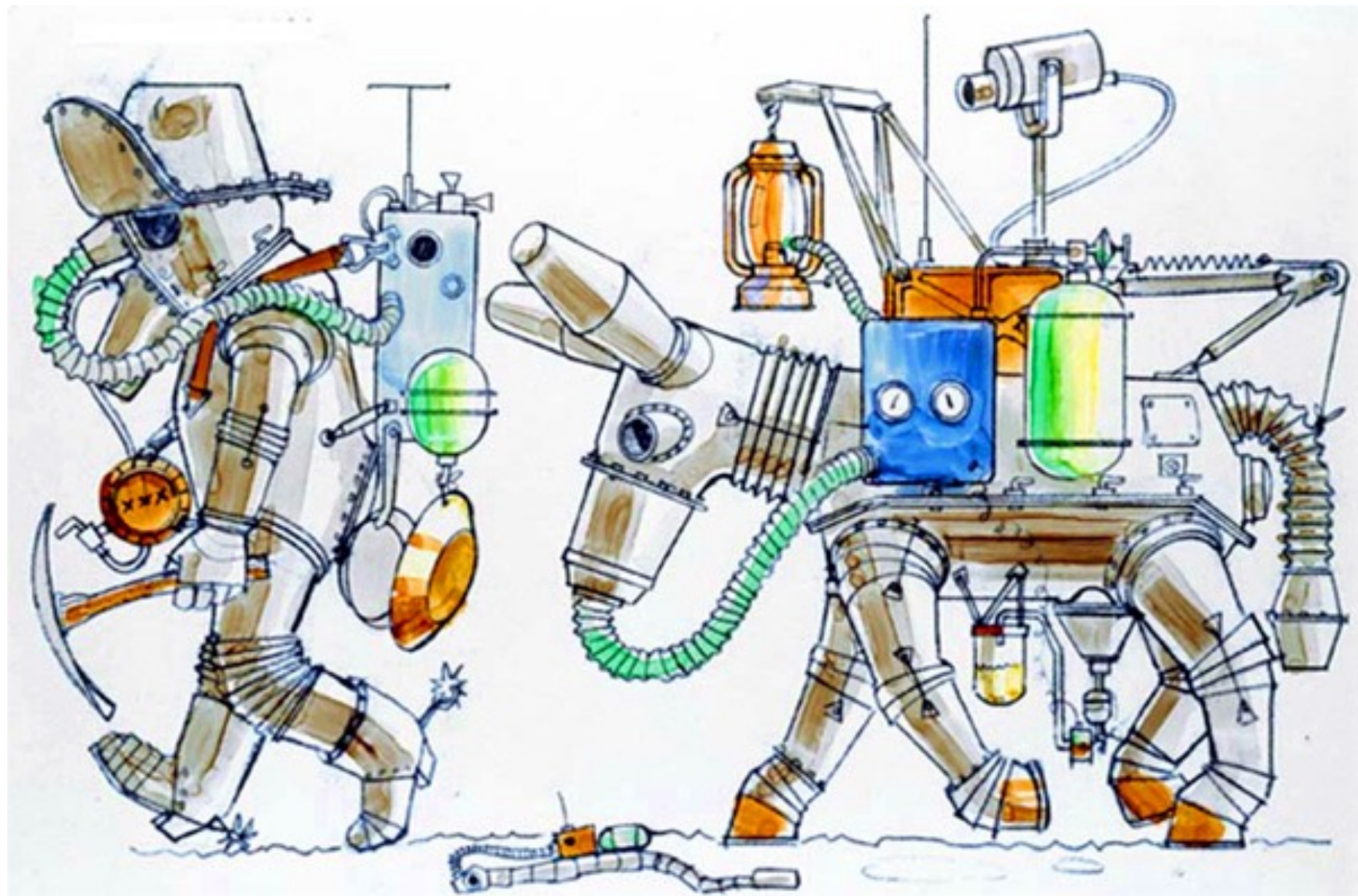


***“Audentes Fortunas Juvat”
Fortune Favors the Bold***

***We’re not where we want to be,
We’re not where we’re going to be,
BUT we’re certainly not where we
were yesterday.***

M.L. King Jr., Jan ‘68





THANK YOU FOR YOUR ATTENTION

Art Dula

art@dula.com